SIR JOSEPH NORMAN LOCKYER—1836-1920

By W. W. Campbell

The recent death of Sir Norman Lockyer has deprived British science of an influential leader, and astronomy of a fruitful pioneer and contributor.

An index to Lockyer's influence upon the development of science, especially in the English-speaking countries, exists in the fact that he founded the weekly illustrated journal of science, *Nature*, and continued to serve as its leading editor as long as he lived. The semicentennial of the founding of this journal, the greatest of all weekly journals devoted to the advancement of science, was celebrated with world-wide felicitations a few months ago. Powerful appeals for the more generous support of scientific research were addressed to the British Government frequently by Lockyer, and not always in vain.

Lockyer's thoughts turned toward the study of the physics of the celestial bodies shortly following the discovery, in 1859, of certain of the fundamental principles of spectrum analysis; and the spectroscope, both in the laboratory and attached to telescopes, was his chief instrumental resource. A review of Lockyer's contributions to our knowledge of celestial bodies will reveal that he dealt effectively and in original ways with a great many important phases of astrophysics. His contributions began, in effect, in 1866, with a spectroscopic study of sun-spots. He noted that the spot spectrum is different in many details from that of the photosphere.

Up to the year 1868 the solar prominences had been observed only at times of total solar eclipse. That year Lockyer of England and Janssen of France independently and simultaneously reached the conclusion that the prominences could be observed and studied at the established observatories on any clear day, without the assistance of eclipse conditions. A high-dispersion spectrograph, with its widened slit in the focus of the image-forming telescope, would supply the necessary equipment. Both astronomers foresaw that the diffused light of the sky, which prevents the observation of the prominences with telescope and eye alone, would be so diluted by the high dispersion of the spectrograph that the prominence images, made up of a few monochromatic radiations, would be visible in the eye-piece. Janssen actually observed the prominences before Lockyer did, in August, 1866, but Lockyer's plans had been

formed much earlier, and his spectrograph, designed and built with reference to prominence observations, was utilized successfully in October, 1868. Lockyer's description of the method and of the results was received by the Paris Academy of Sciences only a few minutes before Janssen's manuscript was handed to the Academy's secretary. The Academy awarded a joint gold medal to Lockyer and Janssen in recognition and honor of their important contributions.

Lockyer's interest in the observation of solar eclipses was intense and continuous. He organized and directed the work of many expeditions for the observation of eclipse phenomena in various parts of the world. Eclipse photographs, obtained by Lockyer and his leading assistants, were the first to distinguish between coronal and chromospheric bright lines. Up to the early '90's the strong hydrogen and calcium bright lines observed with spectroscopes directed to the edge of the eclipsed Sun were attributed (erroneously) to the corona as origin. Lockyer's expeditions established that these radiations are from the prominences and chromosphere, and that the radiations truly coronal do not include the hydrogen, calcium, and helium lines. The bright lines truly coronal are relatively faint.

Lockyer was able to establish that the prominences are merely upheavals of chromospheric matter, under the influence of forces then (and still) unknown. The deep stratum of the Sun known as the *chromosphere* received its name from him.

Lockyer showed that a bright orange line in the spectrum of the chromosphere, previously assigned by some observers to sodium, was in fact not in the position occupied by the well-known sodium pair of lines. He assigned the origin of this line to an unknown and hypothetical element, which he named *helium*. The history of helium investigation, dating from Lockyer's contribution, is one of the romances of physical science.

Lockyer and his assistants, several of whom are now distinguished contributors to astronomical science, were greatly concerned with variations in the laboratory spectra of the elements, as observed under different conditions of excitation: spectra resulting from the gas flame, the electric arc, the electric spark, under a variety of controlled conditions. They were able to show that certain conspicuous lines in the solar prominence spectrum were reproduced in the laboratory under the high temperature conditions of the electric spark, whereas many lines in the sun-spot spectra were observed

in the laboratory spectra of the elements with the lower temperatures of the electric arc. This method of approaching the interpretation of solar and other stellar conditions has been further developed, with genius and great fruitfulness, by Lockyer's former chief assistant, Dr. Fowler.

Lockyer's well-known speculations on the "dissociation" of the chemical elements were suggested by the laboratory observations here described. According to the "dissociation" hypothesis, matter observed on the Earth or in certain low-temperature stars, in the form of recognized chemical elements, would, if transferred to stars of vastly higher temperatures, be transformed into matter simpler in molecular structure; and, vice versa, celestial bodies composed of the simpler chemical elements would, under lower temperature conditions, develop into matter more complex in molecular structure. Contributions by others to the knowledge of molecular structure in the past fifteen years have shown that Lockyer's speculations were based upon philosophic insight and vision. This statement does not imply that his conclusions as to molecular transformations were correct, but he was working close to the right track, and his ideas were highly valuable.

Studies made by Lockyer and his school of assistants as to the so-called "enhanced" lines of the elements have been exceedingly valuable in the interpretation of celestial spectra. When certain specified lines in the spectrum of one star are very prominent (enhanced), and these lines are relatively weak in the spectrum of another star, we may safely say, on the basis of Lockyer's contribution that the stellar temperature in the former case is relatively high, and in the latter case relatively low. It is possible that other factors than heat may also be in question.

More than three decades ago Lockyer put forth a "meteoritic hypothesis" of the origin of celestial bodies, namely: that the self-luminous celestial bodies have resulted from the combination of multitudes of meteoric bodies. The growth of the celestial bodies, by virtue of meteoric accretions, would be slow and long-continued. The coming together of meteoric masses would generate heat, under the influence of the collisions and gravitational condensations. Great gaseous and vaporous bodies known as the radiating nebulae, and stars of low temperature, would result. With the progress of time these bodies would pass thru a sequence of stellar types, as postulated in all existing hypotheses of stellar evolution. It can

scarcely be said that the meteoritic hypothesis was received with marked favor in its early age, but its merits, as the possible representation of a great truth of nature, and as a rich suggestive influence, have increased in the estimation of astronomers with the passing of time. Its possible points of contact with the true story of stellar life are now recognized as numerous.

Lockyer's sequence of stellar evolution postulated that the stars progress with time from relatively low temperatures to the stage of maximum temperatures represented in the very blue stars, and thence decline to stellar states of low temperatures. Russell has in recent years been led to favor this same sequence of evolution, thru a study based chiefly upon stellar densities and stellar absolute magnitudes.

Careful consideration of Lockyer's contributions to astronomy must lead to his recógnition as a bold yet philosophic speculator on the great problems of astrophysics. The impress of his observations and thought will be permanent in many salient particulars. He was not always right. The errors, to which every such active personality is liable, resulted chiefly from the overlooking of essential details, to which the genius of his mind was not strongly attracted. Those who, as students of astronomy, received their impetus in Lockyer's laboratory, have been attending to many of the details with great skill, and are extending the investigations into related and fruitful fields.